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Seismic facies and stratigraphy of the Cenozoic succession in McMurdo Sound, Antarctica: Implications for tectonic, climatic and glacial history

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Abstract A new stratigraphic model is presented for the evolution of the Cenozoic Victoria Land Basin of the West Antarctic Rift, based on integration of seismic reflection and drilling data. The Early Rift phase (?latest Eocene to Early Oligocene) comprises wedges of strata confined by early extensional faults, and which contain seismic facies consistent with drainage via coarse-grained fans and deltas into discrete, actively subsiding grabens and half-grabens. The Main Rift phase (Early Oligocene to Early Miocene) comprises a lens of strata that thickens symmetrically from the basin margins into a central depocenter, and in which stratal events pass continuously over the top of the Early Rift extensional topography. Internal seismic facies and lithofacies indicate a more organized, cyclical shallow marine succession, influenced increasingly upward by cycles of glacial advance and retreat into the basin. The Passive Thermal Subsidence phase (Early Miocene to ?) comprises an evenly distributed sheet of strata that does not thicken appreciably into the depocentre, with more evidence for clinoform sets and large channels. These patterns are interpreted to record accumulation under similar environmental conditions but in a regime of slower subsidence. The Renewed Rifting phase (? to Recent, largely unsampled by coring thus far) has been further divided into 1, a lower interval, in which the section thickens passively towards a central depocentre, and 2, an upper interval, in which more dramatic thickening patterns are complicated by magmatic activity. The youngest part of the stratigraphy was accumulated under the influence of flexural loading imposed by the construction of large volcanic edifices, and involved minimal sediment supply from the western basin margin, suggesting a change in environmental (glacial) conditions at possibly c. 2 Ma.

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Introduction

In recent years, efforts to resolve the Cenozoic history of Antarctica have increasingly focused on the westernmost part of the West Antarctic Rift System, a north-south-elongate sub-basin named the Victoria Land Basin. Data from fully cored drillholes, together with seismic reflection records, have shown that the Victoria Land Basin preserves a relatively complete archive of Cenozoic environmental change, from the latest Eocene (>34 Ma) onward. To date, however, no study has fully integrated the drilling dataset with information from the extensive array of seismic reflection records from the region.


In this paper, we present a stratigraphic framework for the Victoria Land Basin. It draws on seismic reflection records from the McMurdo Sound region and integrates all available drilling data. The internal seismic reflection character of each stratigraphic interval is then described from oldest to youngest, and the insights that these data provide to understanding of Cenozoic basin history and environmental change are summarized. The seismic stratigraphic scheme presented herein is an extension of that published by Fielding et al. (2006), with numerous additions to the younger part of the succession. It recognizes numerous laterally traceable events, many of which correlate to key surfaces of previous workers (Table 1).

Stratigraphy

Based on integration of regional seismic reflection surveys with available drillcore data, the stratigraphic succession of the western Victoria Land Basin in McMurdo Sound, Antarctica, has been resolved into a series of intervals each reflecting changes in basin-forming tectonic processes (Table 1). “Phase 1” of Table 1 refers to formation and exhumation of the Transantarctic Mountains prior to commencement of sediment accumulation in the VLB.

The Early Rift phase (34–29 Ma: “Phase 2” of Table 1) is characterized by a thick succession of mainly coarse-grained lithologies that largely lacks evidence of cyclicity. Lithofacies and seismic facies together suggest progradation of coarse-grained fan and delta systems into progressively opening half-graben infra-basins. Available data suggest that sediments were accumulated in shallow water throughout this interval, indicating a ready supply of terrigenous clastic sediment was able to balance the rapid rate of subsidence. The Main Rift phase (29–23 Ma: “Phase 3” of Table 1) is characterized by a more parallel, continuous reflection character, with a gradual eastward expansion of accommodation associated with the transfer of the depocentre to a more basin-central location. This has been interpreted in terms of repeated cycles of shallow marine to coastal facies, with a cyclical motif becoming increasingly recognizable up-section. Cyclicity

Table 1. Seismic stratigraphic framework for this study, showing interpretation in terms of rift history and correlation to other seismic stratigraphic schemes for the region (modified after Fielding et al., 2006).

Cooper et al., 1987	Brancolini et al., 1995	Bartek et al., 1996	Anderson and Bartek 1992	Horgan et al., 2005	This PAPER		RIFT PHASE
V1				Surface A0		Rk	5b
		A-B					
	RSU 1?	C-D?	3/2?	Surface A1		Rj	
		A-H					
	RSU 2	E-F	5/6	Surface A2	4.6-4.0 Ma Ri		
	RSS 5-8 (MIDDLE MIOCENE IN DSDP273) RSU4 (LOWER MIOCENE IN DSDP 273) RSS4	G-H			Rv		
	RSU 4a		9/10	Surface B	?? 7.5 Ma	Rh	
V2	RSS 3						5a
	RSU 5	L-M	10/11	Surface C		Rg	
V3	RSS 2				17 Ma		4
	~RSU 6	P/Q				Rf	
	R/S						
V4	RSS 1			23 Ma	Re	3	
					Rd		
T				Rc			
V5				29 Ma	Rb	2	
				34 Ma	Ra		
V6		("volcanics")					1
V7		("basement")					

1 – Exhumation of the Transantarctic Mountains, 2 – Early Rift, 3 – Main Rift, 4 – Passive Thermal Subsidence, 5a – Renewed Rifting, lower interval (no significant magmatic products), 5b – Renewed Rifting, upper interval (significant magmatic products). Flexural loading of the lithosphere in the region around Ross Island commenced at about the time of the turquoise reflector.

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